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# EFFECT OF VARIOUS FACTORS ON THE CREAMING ABILITY OF MARKET MILK

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## REASONS FOR INVESTIGATION

Two important qualities of market milk are safety and richness. Most consumers are not in a position to determine with any degree of accuracy the safety of the milk which they receive, but depend upon the health authorities to provide protection. The richness is judged by the housewife almost wholly by the amount of cream that can be seen at the top of the bottle, and not by the actual butterfat content as determined by the Babcock test.

In the pasteurization of milk some difficulty has been experienced with variations in the depth of the cream layer. The consumers who observe this often believe they are receiving milk below the legal requirement in butterfat. A uniform and satisfactory cream layer on pasteurized milk is considered very important by health officials, because it is difficult to induce the public to purchase any grade of milk which does not show a satisfactory cream layer. Moreover, on account of the keen competition that exists among milk dealers, the cream volume on the bottled milk is of great commercial importance.

It has been understood by many plant operators, and some investigators have shown, that pasteurization of milk decreases the cream volume to some extent. From the variation in the cream layer obtained by various dealers, it is apparent that the methods used in pasteurization as well as the effect of other operations in the handling of the milk, both before and after pasteurization, have an important bearing on this problem.

To obtain direct information, a questionnaire was sent to the plants in Minnesota that label their milk "pasteurized" under the approval of the State board of health. The questionnaire asked (1) whether a satisfactory cream layer was obtained on pasteurized milk, and (2) whether the depth of the cream layer was less than, equal to, or greater than that on raw milk of a similar butterfat content. Thirty-one replies were received, and the following are the answers to the first question: Yes, 23; not always, 1; at times, 1; no, 6. Following are the replies to the second question: Greater, 4; equal, 9; the same, 1; less, 10; a trifle less, 4; do not know, 2.

A similar questionnaire was sent by the Bureau of Dairying of the United States Department of Agriculture to the larger milk dealers throughout the country asking whether the cream layer of their product was injured by the pasteurization process. The following are the answers received: Cream volume not injured, 128; cream volume only slightly injured, 31; cream volume injured, 21. Of the 21 dealers who replied that the cream volume was injured, a few specified the percentage of reduction that they estimated had occurred. These estimated reductions varied from less than 10 per cent to 25 per cent.

Replies received to both questionnaires indicated that the majority of the dealers are not experiencing any great difficulty with their present methods of pasteurization.

Studies on the various factors which may or may not affect the creaming ability of market milk were undertaken by the division of sanitation of the Minnesota State Board of Health and the Bureau of Dairying in cooperation.[1] Experiments were carried on in the laboratory of the Minnesota State Board of Health; at the dairy hall of the division of dairy husbandry, University of Minnesota, the facilities of which were kindly turned over to the cooperators by the university; and at commercial milk plants. The laboratory tests included the effect of pasteurizing milk, of storage temperatures, of the rapidity of creaming, etc. The experiments at the dairy hall, University of Minnesota, included the effect of vat pasteurization of milk, using heating media of both high and low temperatures, the effect of cooling after pasteurization to various temperatures, the effect of storage temperatures, the effect of pumping milk with various types of pumps, etc. The experiments at the commercial plants included practically all of the factors previously mentioned, with especial regard to the results obtained with various types of pasteurizing apparatus, and to the effect of other processes that take place at commercial plants.

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[1] Studies were begun by the division of sanitation during March, 1919, and cooperation with the Department of Agriculture, which had previously done some work on the problem, was started during April, 1923.

## METHODS USED

The studies at the plants included a history of the raw milk received and the collection of detailed data on the equipment and methods of operation. Samples were collected during each step of the process, and the cream volume and butterfat percentage were determined. The cream-value determinations were made by placing 100 cubic centimeters of the sample in a graduated cylinder with 1 cubic centimeter graduations. Each cubic centimeter of visible cream in this cylinder represented 1 per cent of the total volume. The cream-volume readings are not referred to in this bulletin as a rate per cent, however, but as units, in order to avoid confusion with other percentage rates. The cream-volume readings were made after the samples had remained in storage for from 20 to 24 hours.

All samples on which cream-volume determinations were made were cooled quickly to approximately 45° F., and then placed at once in the refrigerator, unless otherwise stated. The methods used eliminated the factors of slow cooling and of agitation during cooling in so far as possible.

The percentage of fat in the under layer was determined by placing 100 cubic centimeters of the sample in a glass tube plugged at the bottom with a cork. An outlet tube extended through the cork, by means of which a definite quantity of the under milk could be slowly drawn off. These tubes were placed in the refrigerator with the other samples and the milk was drawn from them at the time the cream-volume readings were made; the milk was then tested for butterfat. These tests are referred to in the tables as "the butterfat in the under layer." These under-layer butterfat tests were made to check the accuracy of the cream-volume readings. Butterfat tests were run on all samples on which cream-volume determinations were made.

In order to eliminate the factor of a high-temperature heating medium in vat pasteurization, a direct-acting piston pump was connected with the pasteurizing vat at the dairy hall, University of Minnesota, so that a large quantity of the heating medium could be pumped through the coil.

## EFFECT OF PASTEURIZING MARKET MILK

Table 1 is a summary of the results of pasteurizing market milk at temperatures varying from 143° to 148° F. Most of these tests were made at commercial plants, though a few of them were conducted in the board of health laboratory and at the dairy hall, University of Minnesota. Unless otherwise stated, the market milk used was that received at commercial pasteurizing plants, varying in age from 4 to 28 hours, with an acidity less than 0.2 per cent.

A study of the table shows that in the majority of cases there was a reduction of approximately two units in cream volume for milk pasteurized at 145° F. for 30 minutes, and a still greater reduction at higher temperatures. In a few cases there was no change, and in some cases the pasteurized sample showed an increase over the raw control sample. In many cases where this occurred, however, the cream volume of the control sample was abnormally low owing to some previous process to which the milk had been subjected. Although in a majority of cases there was a decrease in cream volume as a result of pasteurizing at 145° F., the decrease was not usually great enough to be readily noted on a bottle of milk by consumers.

TABLE 1.—*Effect of temperature of pasteurization on ordinary market milk*

| Test No. | Original raw milk | | Raw control after clarifying or pumping | | Milk pasteurized at— | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 143° F. | | 145° F. | | 147° to 148° F. | |
| | Cream volume[1] | Butter-fat in under layer | Cream volume | Butter-fat in under layer | Cream volume | Butter-fat in under layer | Cream volume | Butter-fat in under layer | Cream volume | Butter-fat in under layer |
| | | *Per cent* | | *Per cent* | | *Per cent* | | *Per cent* | | *Per cent* |
| 1 | (2) | | 11. 5 | 1. 1 | 12. 0 | 0. 75 | 11. 0 | 0. 9 | 8. 5 | 1. 50 |
| 2 | (2) | | 20. 5 | 1. 1 | 19. 5 | . 70 | 16. 0 | | 11. 5 | 1. 40 |
| 3 | (2) | | 20. 5 | 1. 3 | 17. 5 | . 90 | 14. 0 | 1. 35 | 9. 5 | 2. 45 |
| 4 | (2) | | 19. 0 | . 90 | 17. 0 | . 80 | 14. 0 | . 90 | 9. 5 | 1. 65 |
| 5 | 14. 0 | 0. 80 | 13. 0 | . 80 | 13. 0 | . 90 | | | | |
| 6 | 14. 0 | . 7 | 13. 0 | . 80 | 12. 0 | . 95 | | | | |
| 7 | 13. 5 | 1. 2 | 11. 0 | 1. 6 | | | 12. 0 | . 90 | | |
| 8 | 9. 0 | 1. 7 | 9. 0 | 1. 7 | | | 11. 0 | 1. 20 | | |
| 9 | 16. 0 | . 3 | 15. 0 | . 4 | 15. 5 | . 3 | | | 9. 0 | 1. 2 |
| 10 | 12. 5 | 1. 0 | 11. 5 | 1. 3 | | | 18. 5 | 1. 65 | | |
| 11 | 13. 5 | 1. 0 | 11. 0 | | | | 10. 5 | 1. 40 | | |
| 12 | 14. 75 | 1. 0 | 13. 5 | 1. 1 | | | 13. 0 | 1. 0 | 10. 0 | |
| 13 | 7. 0 | 2. 2 | 6. 0 | 2. 4 | | | 9. 5 | 1. 3 | | |
| 14 | 13. 5 | 1. 1 | 12. 5 | 1. 3 | 12. 5 | 1. 25 | 12. 0 | 1. 3 | | |
| 15 | 13. 5 | 1. 1 | 12. 5 | 1. 3 | | | 11. 0 | 1. 4 | | |
| 16 | 16. 0 | . 85 | 14. 0 | 1. 10 | | | 12. 0 | . 9 | 10. 0 | 1. 67 |
| 17 | 16. 0 | 1. 5 | 16. 0 | 1. 5 | | | 16. 0 | . 8 | | |
| 18 | 13. 5 | 1. 2 | 13. 5 | 1. 2 | 12. 5 | . 7 | 11. 5 | 1. 5 | 11. 0 | 1. 6 |
| 19 | 12. 0 | | 11. 5 | | 13. 0 | | 10. 5 | | | |
| 20 | 13. 0 | 1. 5 | 12. 0 | 1. 6 | 12. 0 | . 9 | 9. 0 | 1. 85 | 7. 0 | 2. 15 |
| 21 | 17. 0 | | 17. 0 | | | | | | 11. 5 | |
| 22 | 17. 0 | | 17. 0 | | | | 16. 0 | | | |
| 23 | 14. 75 | | 14. 0 | | | | 13. 0 | | | |
| 24 | 16. 0 | | 16. 0 | | | | 15. 0 | | | |
| 25 | 15. 0 | | 15. 0 | | | | 13. 5 | | | |
| 26 | 15. 0 | | 15. 0 | | | | 13. 0 | | | |
| 27 | 13. 0 | | 14. 0 | | | | 11. 5 | | | |
| 28 | 15. 0 | | 15. 0 | | 13. 5 | | 13. 0 | | | |
| 29 | 14. 0 | | 14. 0 | | | | 12. 0 | | | |
| 30 | 14. 0 | | 14. 0 | | | | 12. 0 | | | |
| 31 | 15. 0 | | 15. 0 | | | | 12. 5 | | | |
| 32 | 15. 0 | | 15. 0 | | 13. 5 | | 12. 5 | | | |
| 33 | 13. 0 | | 13. 0 | | 14. 0 | | 11. 5 | | | |
| 34 | 14. 0 | | 13. 0 | | | | 11. 5 | | | |
| 35 | 14. 0 | | 14. 0 | | | | 9. 0 | | | |
| 36 | 13. 0 | | 12. 0 | | | | 11. 0 | | | |
| 37 | 14. 0 | | 13. 5 | | | | 11. 0 | | | |
| 38 | 13. 5 | | 13. 5 | | | | 11. 0 | | | |

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[1] Cream volume is the number of cubic centimeters of cream rising to the top of 100 cubic centimeters of milk left standing for 20 to 24 hours in a straight-sided graduated cylinder. (See page 3.)

[2] Samples 1 to 4, inclusive, were pasteurized in the laboratory, and samples 28 to 33, inclusive, were pasteurized at the dairy hall of the division of dairy husbandry, University of Minnesota. All others were taken at commercial pasteurizing plants.

## EFFECT OF HEATING MILK TO VARIOUS TEMPERATURES

In Table 2 are shown the results of heating milk to temperatures varying from 138° to 148° F. All these samples were taken before the milk was subjected to the 30-minute holding period.

The control samples upon which the percentages of difference in this table are computed were from the raw milk entering the heater; and in the case of vat pasteurizers, just before the heating medium was turned on. In some instances the milk had been clarified or pumped, or both, depending upon the routine procedure carried out at the plant where it was collected.

TABLE 2.—*Effect of heating milk to various temperatures without holding at pasteurization plants*

| Temperature to which heated | Percentage of increase (+) or decrease (−) | | Temperature to which heated | Percentage of increase (+) or decrease (−) | | Temperature to which heated | Percentage of increase (+) or decrease (−) | |
|---|---|---|---|---|---|---|---|---|
| | Cream volume | Butterfat in under layer | | Cream volume | Butterfat in under layer | | Cream volume | Butterfat in under layer |
| ° F. | | | ° F. | | | ° F. | | |
| 138 | +6.6 | −50 | 144.5 | −4.3 | Not tested. | 146 | +7.1 | −36.6 |
| 142 | 0 | +12.5 | 145 | −6.6 | Not tested. | 146 | +55.6 | −76.5 |
| 142 | +4 | −50 | 145 | +9.1 | Not tested. | 146 | −3.7 | −22.7 |
| 143 | +3.3 | −50 | 145 | +83.3 | −52.1 | 146 | 0 | −27.5 |
| 143 | +13.6 | Not tested. | 145 | −3.7 | −22.7 | 146 | +8.3 | −62.5 |
| 143 | +7.4 | −45.4 | 145 | +8 | −38.4 | 146.5 | +8.7 | −30.8 |
| 143 | −3.7 | −22.7 | 145.5 | +13.6 | Not tested. | 147 | −6.6 | +33.3 |
| 143.5 | −8.7 | Not tested. | 145.5 | +31.8 | −57.9 | 148 | +8.3 | −62.5 |
| 143.5 | +4.2 | −50 | 145.5 | +6.1 | −74 | | | |
| 144.5 | +3.5 | −45.4 | 145.5 | 0 | Not tested. | | | |

An examination of Table 2 shows the following facts:

In the 11 tests at temperatures from 138° to 144.5° F., 7 samples show increases in the cream volume ranging from 3.3 to 13.6 per cent, 1 sample shows the same depth of cream volume, and 3 show decreases ranging from 3.7 to 8.7 per cent.

In the 9 tests at temperatures from 145° to 145.5° F., 6 show increases ranging from 6.1 to 83.3 per cent, 1 shows the same depth of cream volume, and 2 show decreases ranging from 3.7 to 6.6 per cent.

In the 8 tests at temperatures from 146° to 148° F., 5 show increases ranging from 7.1 to 55.6 per cent, 1 shows the same depth of cream volume, and 2 show decreases ranging from 3.7 to 6.6 per cent.

Twenty-one tests of the butterfat percentage in the under layers are contained in this table. In all but two samples there is a decrease in the butterfat percentage in the under layer of milk ranging from 22.7 to 76.5 per cent.

The decrease in the butterfat percentage of the under layer of milk in practically all of the samples seems to indicate that heating milk to temperatures of from 138° to 145° F. causes an increased separation of the butterfat.

In several instances where the cream depth had been seriously lessened as a result of previous steps in the processing, momentary heating apparently restored the creaming ability equal to that of the raw, unprocessed milk. Some of the apparently large increases found upon heating the milk were without doubt due to the fact that the raw milk did not show a normal cream volume.

## EFFECT OF HEATING AND HOLDING MILK FOR 30 MINUTES AT VARIOUS TEMPERATURES AT PASTEURIZATION PLANTS

Table 3 is a summary of the results of pasteurization tests at commercial milk plants. The table indicates the temperature to which the milk was heated and held, the temperature of the heating medium, the amount of agitation during heating and holding, and the time required to heat the milk. All samples included in this table were cooled without agitation to a temperature of approximately 42° F. as soon as collected.

TABLE 3.—*Effect of heating and holding milk for 30 minutes at various temperatures at pasteurization plants*

| Temperature at which milk was held for 30 minutes | Percentage increase or decrease | | Character of agitation | | Temperature of heating medium | Time required to heat milk |
|---|---|---|---|---|---|---|
| | Cream volume | Butterfat in under layer | Heating | Holding | | |
| *° F.* | | | | | *° F.* | *Minutes* |
| 149 | −32.3 | | Agitator, 200 r. p. m. | Agitator, 200 r. p. m. | Steam at 5 lbs. pressure | 25 |
| 147 | −41.7 | +34.4 | Coil, 38 r. p. m. | None | 180 | 53 |
| 147 | −40 | +20 | None | Slowly moving paddle | Not over 160 | 2 to 3 |
| 148–146 | −18.5 | +45.4 | Coil, 38 r. p. m. | None | Not over 155 | 65 |
| 146.5–146 | −26.1 | +26.9 | Coil, 60 r. p. m. | do | Over 180 | 20 |
| 146 | −28.5 | +50 | None | Slowly moving paddle | Not over 155 | 2 to 3 |
| 146–145.5 | −25.9 | | Coil, 38 r. p. m. | None | Not over 180 | 48 |
| 146–145 | −25.0 | +15.6 | do | do | 180 | 50 |
| 146–145 | −14.8 | +36.3 | do | do | Not over 155 | 58 |
| 146–145 | −13.4 | | do | Coil, 38 r. p. m. | do | 24 |
| 146–145 | −16.7 | | do | do | do | 20 |
| 146–145 | +22.2 | −29.4 | Slowly moving paddle | Slowly moving paddle | Not over 160 | 45 |
| 145.75–145 | −7.1 | | do | do | Not over 200 | 40 |
| 145.75–145 | −12.5 | | Coil, 38 r. p. m. | Coil, 38 r. p. m. | Not over 170 | 40 |
| 145.75–145 | −12.5 | | do | None | do | 40 |
| 145.75–145 | −6.3 | | do | Coil, 38 r. p. m. | do | 40 |
| 145.75–145 | −14.3 | | do | do | Not over 155 | 20 |
| 145.75–145 | −13.3 | | do | do | do | 30 |
| 146–145 | 0 | | Agitator, 200 r. p. m. | None | Steam at 5 lbs. pressure | 29 |
| 145.4–145 | −8.7 | | Coil, 46 r. p. m. | Coil, 46 r. p. m. | Not over 160 | 90 |
| 145.5–145 | −4.5 | | Coil, 60 r. p. m. | None | Over 180 | 20 |
| 145.5–145 | 0 | −46.6 | Coil, 32 r. p. m. | do | Not over 155 | 25 |
| 145.5–145 | +9.1 | −43.7 | Slowly moving paddle | Slowly moving paddle | Not over 160 | 45 |
| 145 | −14.2 | −18.2 | None | do | 148–150 | 2 to 3 |
| 145 | −10 | | Slowly moving paddle | None | Under 200 | 43 |
| 145 | −13.4 | | Coil, 32 r. p. m. | do | Not over 155 | 24 |
| 145–144.75 | −12 | +7.7 | Coil, 38 r. p. m. | Coil, 38 r. p. m. | do | 62 |
| 145–144.75 | −4.0 | 0 | do | None | do | 62 |
| 145–144.5 | −3.7 | −6.1 | do | Coil, 38 r. p. m. | Not over 180 | 48 |
| 144.5–144 | −57.7 | | Coil, 46 r. p. m. | None | Not over 160 | 105 |
| 143 | −10 | | Coil, 38 r. p. m. | do | Not over 155 | 22 |
| 143 | −6.3 | | do | do | do | 22 |
| 143 | −11.1 | −9.1 | do | do | Not over 180 | 47 |
| 143 | 0 | −43.7 | do | do | 180 | 47 |
| 143 | +3.3 | −25.0 | None | Slowly moving paddle | Not over 160 | 2 to 3 |
| 143–142.75 | 0 | −36.7 | Coil, 38 r. p. m. | None | Not over 155 | 52 |
| 143–142 | −10 | | do | Slight | do | 20 |
| 143–142 | +7.7 | | Agitator, 200 r. p. m. | None | | 26 |
| 142 | 0 | −3.9 | Coil, 38 r. p. m. | do | | 59 |
| 143.5–141 | +8.7 | | Coil, 46 r. p. m. | do | Not over 160 | 100 |
| 142–141 | 0 | +12.5 | Coil, 38 r. p. m. | do | Over 180 | 26 |
| 142–141 | −7.3 | +18.2 | do | Coil, 38 r. p. m. | do | 26 |
| 142.5–140 | +13 | | Coil, 46 r. p. m. | None | Not over 160 | 90 |

The control samples upon which the percentages of difference are computed were taken from the raw milk entering the heater; and, in the case of vat-type pasteurizers, just before the heating medium was turned on. Examination of the data contained in this table shows the following facts:

In six tests at temperatures ranging from a maximum of 148° F. at the beginning to a minimum of 145.5° at the end of the holding period, there was in every instance a decrease in the cream volume, ranging from 18.5 to 41.7 per cent, with an average of 31.1. In five tests of the butterfat percentage in the under layer at these temperatures, there were increases ranging from 20 to 50 per cent.

In 19 of the tests at temperatures not over 146° at the beginning and not less than 145° at the end of the holding period, 2 showed increases of 22.2 per cent and 9.1 per cent, and 2 showed no change, while 15 showed decreases ranging from 4.5 per cent to 25 per cent. In 6 tests of the butterfat percentage of the under layer at these temperatures, 4 showed decreases ranging from 18.2 to 46.6 per cent, while 2 showed increases of 15.6 and 36.3 per cent, respectively.

In four tests at temperatures not over 145° at the beginning and not less than 144° at the end of the holding period, all showed decreases in cream volume varying from 3.7 to 57.7 per cent. Three butterfat tests of the under layer at these temperatures showed the butterfat content decreased 6.1 per cent in one case, increased 7.7 per cent in one case, and remained unchanged in 1 case.

In 13 tests at temperatures of not more than 144° F. at the beginning and not less than 140° at the end of the holding period, 4 showed increases ranging from 3.3 to 13 per cent, 4 remained unchanged, and 5 showed decreases ranging from 6.3 to 11.1 per cent. In 7 tests at these temperatures, 2 of the butterfat percentages in the under layer showed increases of 12.5 and 18.2 per cent and 5 showed decreases ranging from 3.9 to 43.7 per cent.

The temperature of the heating medium varied from not more than 155° F. to that of steam at 5 pounds pressure. Although the number of tests with the heating medium at various temperatures is not sufficient to permit definite conclusions to be drawn, with the equipment used in these tests the high-temperature medium did not cause any greater decrease than a low-temperature medium. There was no apparent effect from agitation during heating as ordinarily used at the plants; nor did the time required to heat the milk to the desired temperature by the various types of apparatus used at the plants have any apparent significance.

It was noted that in vat or tank pasteurization, in the majority of instances, agitation during the holding period under the methods described resulted in little or no change in the cream volume as compared with holding the milk during the 30-minute period without agitation.

## EFFECT OF PASTEURIZING FRESH MILK

Table 4 is a summary of 10 tests made in the laboratory on the effect of pasteurizing fresh milk at various temperatures. It will be noted that in several cases there was an increase in cream volume for milk pasteurized at 143° F. All samples pasteurized at 145° showed a decrease in cream volume, with the exception of sample No. 6, which showed a slight increase. All samples pasteurized at 148° showed a marked decrease in cream volume. (Compare with results of pasteurizing old milk, as shown in Table 5.)

## EFFECT OF PASTEURIZING OLD MILK

In Table 5 are seen the results of tests made to show the effect of pasteurizing milk 30 to 36 hours old that had been recreamed at least once. The raw old milk showed a poorer cream volume than raw fresh milk of the same butterfat content, so that the reduction from pasteurizing old milk is not so marked as in the case of pasteurizing fresh milk.

TABLE 4.—*Effect of temperature of pasteurization on fresh milk*

| Test No. | Raw |  | Milk pasteurized at— |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  |  |  | 143° to 142° F. |  | 145° F. |  | 148° to 147° F. |  |
|  | Cream volume | Butter-fat in skim milk | Cream volume | Butter-fat in skim milk | Cream volume | Butter-fat in skim milk | Cream volume | Butter-fat in skim milk |
| 1 | 15.0 | 0.8 | 14.0 | 0.3 | 13.5 | 0.5 | 9.5 | 1.50 |
| 2 | 14.5 | 1.6 | 14.0 | 1.05 | 11.5 | 1.80 | 9.5 | 2.35 |
| 3 | 14.5 | 1.6 | 13.0 | 1.10 | 9.0 | 2.15 | 9.0 | 2.10 |
| 4 | 11.5 | 1.0 | 12.5 | .75 | 10.5 | 1.55 | 8.0 | 2.11 |
| 5 | 11.5 | 1.0 | 12.5 | .65 | 11.0 | 1.00 | 8.0 | 2.70 |
| 6 | 10.0 | 1.15 | 11.5 | .70 | 10.5 | .90 | 8.5 | 1.35 |
| 7 | 10.0 | 1.15 | 10.0 | .90 |  |  | 7.0 | 1.85 |
| 8 | 11.0 |  |  |  | 9.0 | 1.85 |  |  |
| 9 | 16.5 | .50 | 15.5 | .50 | 14.5 | 1.00 | 11.0 | 2.1 |
| 10 | 13.0 |  | 12.0 |  | 8.0 |  | 6.5 |  |

Tests made in laboratory, heating medium never above 155° F. Time required to heat, 10 to 15 minutes. Acidity of raw milk, less than 0.2 per cent. All samples cooled to 46° F., and stored at 43° to 45° F.

By recreaming is meant allowing the cream to rise a second time. That is, after the cream had once risen the sample was shaken or agitated so that the cream and milk were thoroughly mixed. It was then allowed to stand to permit the cream to rise again.

In nearly all cases there was considerable increase in cream volume for the milk pasteurized at 143° F., and a slightly less increase at 145°, over the raw milk. This increase was without doubt due to the fact that owing to the age and recreaming of the raw milk it had a small cream volume as compared with the original fresh milk. As shown in Tables 13 and 14, the age and recreaming of the raw milk tends to decrease the cream volume as compared with the fresh milk. The results shown in Table 5 indicate that pasteurization at a temperature of not over 145° F. tends to restore the creaming ability of old milk. There was a reduction in all but one instance where the milk was pasteurized at 148° to 147° F. (Compare with results of pasteurizing fresh milk shown in Table 4.)

TABLE 5.—*Effect of temperature of pasteurization on milk 30 to 36 hours old that had been recreamed—Laboratory tests*

| Test No. | Raw milk |  | Milk pasteurized at— |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  |  |  | 143° to 142° F. |  | 145° F. |  | 148° to 147° F. |  |
|  | Cream volume | Butterfat in skim milk | Cream volume | Butterfat in skim milk | Cream volume | Butterfat in skim milk | Cream volume | Butterfat in skim milk |
|  |  | *Per cent* |  | *Per cent* |  | *Per cent* |  | *Per cent* |
| 1 | 11.5 | 1.1 | 12.0 | 0.65 | 11.5 | 0.95 |  |  |
| 2 | 10.5 | 2.0 | 11.5 |  | 9.5 | 1.90 | 9.0 | 2.00 |
| 3 | 8.5 | 1.00 | 12.0 | .70 | 10.5 | 1.20 | 9.0 | 1.70 |
| 4 | 10.0 | 1.45 | 12.0 | .70 | 10.0 | 1.15 | 9.0 | 1.70 |
| 5 | 8.5 | 1.45 | 11.0 | .75 | 10.5 | 1.20 | 7.5 | 1.95 |
| 6 | 9.5 | 1.50 | 11.5 | .70 | 9.5 | 1.40 | 7.5 | 1.80 |
| 7 | 9.5 |  |  |  | 10.0 |  |  |  |
| 8 | 11.5 | 2.00 | 15.5 | .50 | 14.5 | 1.0 | 11.0 | 2.00 |

## EFFECT OF PARTIALLY COOLING PASTEURIZED MILK IN VAT OR TANK

At many plants using tanks or vats for pasteurization it is customary to cool the milk partially in the tank or vat before it is run over the cooler. In this way the capacity of the apparatus is increased and considerable time is saved. At some plants the milk is entirely cooled in the vat. In the laboratory tests reported in Tables 19 to 21 it is shown that holding or agitating pasteurized milk for any length of time at temperatures between 110° and 60° F. had a detrimental effect on its creaming ability.

In Table 6 is shown a summary of the results of partially or wholly cooling the pasteurized milk in the tank or vat. The results shown in this table corroborate the laboratory results shown in Tables 19 to 21. The control samples upon which the percentage differences in this table are computed were from the pasteurized milk at the end of the 30-minute holding period, immediately cooled. The table shows the time and the temperature at which the milk was pasteurized and the agitation to which it was subjected during the subsequent period prior to cooling over the cooler, and the range of temperature at which it was held. At some plants where large tanks or vats were used the milk, after the 30-minute holding period, was held for over an hour in the tank or vat before it was finally cooled. It will be noted that reductions in cream volume where the entire cooling was done in the vat were 20 per cent in one instance and 23.9 per cent in another instance. Of the 27 tests made, 10 showed no reduction for milk held at various temperatures before cooling as compared with the milk that was immediately cooled. It will be noted that in only 4 instances where there was no reduction in cream volume was the milk held at a temperature as low as 110° F., and in only 2 instances was it below 110° F. At temperatures ranging from 145° to 115° the reductions were very small. The results indicate that it is not advisable to cool the pasteurized milk below 115° to 110° in the vat, and that it should be cooled quickly from this temperature to below 50° over a separate cooler.

There is considerable range in the reduction in the cream volume on milk held at various temperatures after pasteurization for various lengths of time. A decrease in creaming ability during this stage of the processing results in variations in the depth of the cream volume in the bottled milk, as the first milk leaving the holding vat will show a deeper cream volume than the last milk discharged. The maximum reduction obtained would be noticeable to consumers and is perhaps one of the causes of complaints received by dealers on the lack of uniformity in the cream volume of their product. However, the data obtained seemed to indicate that the temperature at which the milk is held after pasteurization is much more important than the length of time it is held. Milk held for nearly 1 hour after the 30-minute holding period at 145° F. in many cases showed a better cream layer than milk held after pasteurization for only a few minutes at temperatures between 110° and 60° F.

TABLE 6.—*Effect of holding milk after pasteurization and prior to cooling*

| Sample No. | Temperature of pasteurization | Agitation | Time subsequently held | Temperature at which subsequently held | Increase or decrease | |
|---|---|---|---|---|---|---|
| | | | | | Cream volume | Butterfat in under layer |
| | °*F.* | | *Minutes* | °*F.* | *Per cent* | *Per cent* |
| 1 | 142–141 | Coil, 38 r. p. m. | 45 | 141–140 | 0 | 0 |
| 2 | 146–145 | Slight | 30 | 145–110 | −4.5 | +8.3 |
| 3 | 145.5–145 | Coil, 60 r. p. m. | 17 | 145–95 | −14.2 | +3.4 |
| 4 | 145–145.5 | Coil, 38 r. p. m. | 30 | 145–140 | −7.7 | +20.0 |
| 5 | 145–144 | Slight | 6 | 144 | 0 | 0 |
| 6 | 145–144.75 | Coil, 38 r. p. m. | 30 | 144.75–140 | −4.5 | +3.5 |
| 7 | 145.5–145 | do | 45 | 145–110 | −6.2 | +31.2 |
| 8 | 146–145 | do | 60 | 145–110 | −4.3 | +6.6 |
| 9 | 145.5–145 | do | 30 | 145–110 | 0 | |
| 10 | 146–145 | do | 40 | 145–110 | −11.1 | +5.4 |
| 11 | 146–145 | do | 45 | 145–60 | −15.4 | |
| 12 | 146–145 | do | 72 | [1] 145–48 | −23.9 | |
| 13 | 145 | do | 50 | 145 | 0 | |
| 14 | 146–145 | do | 20 | 145–110 | +6.7 | |
| 15 | 146–145 | do | 35 | 145–80 | 0 | |
| 16 | 146–145 | do | 45 | 145–70 | −8.0 | |
| 17 | 146–145 | do | 58 | 145–60 | −16.0 | |
| 18 | 146–145 | do | 65 | [1] 145–53 | −20.0 | |
| 19 | 146–144 | Agitator revolved | 60 | 144–125 | 0 | |
| 20 | 145.75–145 | Paddle | 25 | 145–120 | 0 | |
| 21 | 145.75–145 | do | 35 | 145–110 | −6.7 | |
| 22 | 146–145 | Coil, 38 r. p. m. | 20 | 145–115 | 0 | |
| 23 | 146–145 | do | 40 | 145–80 | −7.7 | |
| 24 | 145.75–145 | do | 20 | 145–120 | +9.3 | |
| 25 | 145 | None | 45 | 145–110 | 0 | |
| 26 | 145 | do | 60 | 145–100 | −3.8 | |
| 27 | 145 | do | 72 | 145–90 | 0 | |

[1] Entire cooling in vat.

## EFFECT OF THE TEMPERATURE TO WHICH MILK IS COOLED AFTER PASTEURIZATION

To determine what effect, if any, the temperature to which the milk is cooled after pasteurization has on the cream volume, milk was heated to 145° F. for 30 minutes, and samples were then immediately cooled to various temperatures. Two types of cooler were used, a conical and a small corrugated tubular cooler. Some of the samples were cooled on one cooler and some on the other. Brine was used in both coolers, and there was very little agitation of the milk during the cooling process. Samples 10 and 11 were not cooled over a separate cooler. All samples were stored at a temperature below 40° F. and the readings were made after 20 hours. The results of the tests are shown in Table 7:

TABLE 7.—*Effect on cream volume of temperature to which milk is cooled after pasteurization*

| Sample No. | Description | Temperature to which cooled | Type of cooler used | Cream volume |
|---|---|---|---|---|
| | | °*F.* | | |
| 1 | Raw milk as received at 70° F. Butterfat 3.75 per cent | [1] | | 14.0 |
| 2 | Raw milk | 48 | Tubular | 14.0 |
| 3 | do | 52 | Conical | 14.0 |
| 4 | Pasteurized milk | 73 | do | 10.0 |
| 5 | do | 63 | do | 10.0 |
| 6 | do | 54 | Tubular | 10.5 |
| 7 | do | 51 | do | 11.0 |
| 8 | do | 48 | do | 11.0 |
| 9 | do | 41 | do | 11.5 |
| 10 | do | 107 | Cooled in can | 10.0 |
| 11 | do | 52 | Cooled in 1½ hours in can | 7.0 |

[1] Not cooled.

The importance of cooling the pasteurized milk to a low temperature before placing in storage is clearly illustrated in this table. There was no difference in the cream volume in the sample cooled to 107° F. as compared with those cooled to 63° and 73°, but the samples cooled below 55° showed an increase. The samples cooled to 54° showed a cream volume of 10.5, and each sample cooled below this temperature showed a consistently greater cream volume, the largest, 11.5, being on the sample cooled to 41° F.

The milk that was cooled in the can to 52° F. in one and one-half hours showed a cream volume of only 7. This illustrates the fact, elsewhere shown, that the cream layer is injured by slow cooling through certain temperatures, and is comparable to vat cooling to a temperature below 50°.

There was no difference between the cream volume of the raw samples that were cooled and those that were set in storage room at a temperature of 70° F., the temperature of cooling apparently having less effect on the raw milk.

In Table 8 are shown results of cooling pasteurized milk immediately to various temperatures, and of cooling to various temperatures slowly in the can and then cooling immediately to 45° F. over a separate cooler.

TABLE 8.—*Effect of cooling pasteurized milk to various temperatures at once, and of partially cooling in tank*

| Sample No. | Description | Temperature to which cooled | Cream volume |
|---|---|---|---|
| | | ° *F.* | |
| 1 | Raw | 45 | 17.5 |
| 2 | Pasteurized, cooled at once | 45 | 16.0 |
| 3 | do | 47 | 15.0 |
| 4 | do | 52 | 11.0 |
| 5 | do | 58 | 12.0 |
| 6 | Pasteurized, cooled in tank to 90° F. then cooled at once | 45 | 16.0 |
| 7 | Cooled in tank to 80° F. then cooled at once | 45 | 16.0 |
| 8 | Cooled in tank to 70° F. then cooled at once | 45 | 15.0 |
| 9 | Cooled in tank to 60° F. then cooled at once | 45 | 13.5 |

These results also show the advantage of cooling milk quickly after pasteurization to a low temperature. The cooling in the tank to 80° F. did not seem to injure the cream layer. This cooling was done more quickly, however, and with less agitation than is the case with commercial vat pasteurizers. (See Table 6 in regard to cooling in vat.)

## EFFECT OF STORAGE TEMPERATURE

The temperature at which the milk is stored has an important bearing on the creaming ability. Duplicate samples of both raw and pasteurized milk were stored at two different temperatures, one at a low temperature of 38° to 48° F. and the other at a comparatively high temperature of 50° to 60° F. The results are shown in Tables 9 and 10. With nine tests on raw milk, the difference in cream layer between the samples of milk stored at the two temperatures was 28.6 per cent.

In the pasteurized milk there was not so great a difference in cream volume for the two temperatures. The average difference in favor of the colder temperature for 12 samples of pasteurized milk was 10.9 per cent, varying from 0 to 24 per cent.

These tests show the importance of maintaining a low temperature in the storage room. This factor, according to these experiments, has a greater effect on the cream volume than has the heating and holding of the milk at 145° F. For this reason it is extremely important to store milk at a low temperature after pasteurization.

TABLE 9.—*Effect of storage temperature on raw milk*

| Test No. | Cream volume | | Decrease at higher temperature | |
|---|---|---|---|---|
| | In storage at 38° to 48° F. | In storage at 50° to 60° F. | Volume | Per cent |
| 1 | 12.0 | 7.5 | 4.5 | 38 |
| 2 | 12.0 | 6.0 | 6.0 | 50 |
| 3 | 10.5 | 8.0 | 1.5 | 14 |
| 4 | 12.0 | 6.0 | 6.0 | 50 |
| 5 | 13.0 | 11.5 | 1.5 | 11 |
| 6 | 10.5 | 9.0 | 1.5 | 14 |
| 7 | 10.0 | 8.0 | 2.0 | 20 |
| 8 | 15.0 | 10.0 | 5.0 | 33 |
| 9 | 15.0 | 11.0 | 4.0 | 27 |
| Average | 12.2 | 8.6 | 3.6 | 28.6 |

TABLE 10.—*Effect of storage temperature on pasteurized milk*

| Test No. | Cream volume | | Decrease at higher temperature | |
|---|---|---|---|---|
| | In storage at 38° to 48° F. | In storage at 50° to 60° F. | Volume | Per cent |
| 1 | 9.5 | 8.0 | 1.5 | 16 |
| 2 | 8.0 | 7.5 | 0.5 | 6 |
| 3 | 7.5 | 6.5 | 1.0 | 13 |
| 4 | 8.0 | 8.0 | 0.0 | 0 |
| 5 | 8.5 | 7.5 | 1.0 | 12 |
| 6 | 10.0 | 9.0 | 1.0 | 10 |
| 7 | 12.5 | 9.5 | 3.0 | 24 |
| 8 | 12.5 | 11.0 | 1.5 | 12 |
| 9 | 12.0 | 11.0 | 1.0 | 9 |
| 10 | 13.0 | 12.0 | 1.0 | 8 |
| 11 | 12.5 | 12.0 | 0.5 | 4 |
| 12 | 12.0 | 10.0 | 2.0 | 17 |
| Average | 10.5 | 9.3 | 1.2 | 10.9 |

## EFFECT OF STORAGE TEMPERATURE ON RAPIDITY OF CREAMING

Table 11 includes the results of laboratory tests to show the effect of various storage temperatures on the rapidity of creaming. It will be noted that at all three storage temperatures the pasteurized samples, excepting those pasteurized at 148° to 147° F., as a rule showed as much or more cream volume after the first hour as after 20 hours. The lower storage temperature was of more importance in the case of the raw milk than in the case of the pasteurized. It will be noted that, while the pasteurized samples stored at the lower temperatures showed greater cream volume than those stored at the higher temperatures, the difference in favor of the lower storage temperatures was much greater in the case of the fresh raw milk. At the higher storage temperatures the raw samples showed less cream volume after 20 hours than the pasteurized samples, excepting those pasteurized at 148° to 147° F.

TABLE 11.—*Effect of various storage temperatures on the rapidity of creaming—Laboratory experiment*

[All samples cooled to 42° F.]

| Test No. | Character of milk | Storage temperature | Cream volume after number of hours indicated | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ½ | 1 | 1½ | 2 | 2½ | 3 | 3½ | 4 | 6 | 8 | 20 |
| | | *° F.* | | | | | | | | | | | |
| 1 | Fresh raw | 66 | 0 | 0 | 12 | 13 | 13 | 13 | 13 | 12. 5 | 12. 5 | 12 | 11. 5 |
| | | 54 | 0 | 0 | 12 | 13. 5 | 14 | 14 | 14 | 13. 5 | 13 | 13 | 12 |
| | | 42 | 0 | 0 | 18 | 18. 5 | 19 | 19 | 19 | 18. 5 | 18 | ------ | 16. 5 |
| 1 | Pasteurized at 143° to 142° | 66 | 0 | 15 | 15 | 18 | 18 | 17 | 17 | 16. 5 | ------ | 15 | 14 |
| | | 54 | 0 | 15 | 15. 5 | 17. 5 | 17. 5 | 17. 5 | 17. 5 | 17 | ------ | 16 | 14 |
| | | 42 | 0 | 17. 5 | 17. 5 | 18. 5 | 18. 5 | 18. 5 | 18 | 17. 5 | ------ | ------ | 15. 5 |
| 1 | Pasteurized at 145.5° to 145° | 66 | 0 | 14. 5 | 14. 5 | 14. 5 | 14. 5 | 14. 5 | 14. 5 | 14. 5 | ------ | 14. 5 | 13 |
| | | 54 | 0 | 13. 5 | 14 | 14. 5 | 15. | 15 | 15 | 14. 5 | ------ | 14. 5 | 13 |
| | | 42 | 0 | 15 | 15. 5 | 16 | 16 | 16 | 15. 5 | 15. 5 | ------ | ------ | 14. 5 |
| 1 | Pasteurized at 148° to 147° | 66 | 0 | . 5 | 4 | 6 | ------ | 7 | ------ | 7 | ------ | 6. 5 | 8. 5 |
| | | 54 | 0 | 3 | 5 | 8 | ------ | 8 | ------ | 8. 5 | ------ | 9 | 9. 5 |
| | | 44 | 0 | 3 | 6 | 8 | ------ | 9 | ------ | 9. 5 | ------ | ------ | 11 |
| 2 | Old raw | 63 | 0 | 7 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 10. 5 |
| | | 53 | 0 | 3 | 10 | 11 | 11. 5 | 11. 5 | 11. 5 | 11. 5 | 11. 5 | 11. 5 | 11. 5 |
| | | 42 | 0 | 2 | 9 | 11. 5 | 12 | 12 | 12 | 12 | 12 | 12 | 11. 5 |
| 2 | Pasteurized at 143° to 142° | 66 | 0 | 17 | 17 | 17 | 16 | 16. 5 | 16 | 16 | 16 | 15 | 13 |
| | | 53 | 0 | 17 | 17 | 17. 5 | 17 | 16. 5 | 16 | 16 | 16 | 15 | 14 |
| | | 42 | 0 | 18 | 18. 5 | 19 | 18 | 18 | 17. 5 | 17. 5 | 17 | 17 | 15. 5 |
| 2 | Pasteurized at 145.5° to 145° | 66 | 0 | 14. 5 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 14 | 12 |
| | | 53 | 0 | 14 | 15 | 16 | 15. 5 | 15. 5 | 15. 5 | 15. 5 | 15. 5 | 14 | 13. 5 |
| | | 42 | 0 | 14 | 15. 5 | 16. 5 | 16. 5 | 16. 5 | 16. 5 | 16. 5 | 16 | 15. 5 | 14. 5 |
| 2 | Pasteurized at 148° to 147° | 66 | 0 | 1 | 3 | 5 | 6 | 6 | 7 | 7 | ------ | 7 | 8. 5 |
| | | 53 | 0 | 2 | 4 | 7 | 8. 5 | 8. 5 | 9. 5 | 9. 5 | ------ | 10 | 10. 5 |
| | | 42 | 0 | 2 | 4 | 7 | 7. 5 | 9. 5 | 10 | 10 | ------ | 10 | 11 |

## RAPIDITY OF CREAMING OF RAW AND PASTEURIZED MILK

In Table 12 are given the results of laboratory tests to show the rapidity of creaming of raw and pasteurized milk; all samples were cooled to 42° F. and stored at 48°. It will be noted in this table as well as in Table 11 that the pasteurized samples, excepting those pasteurized at 147° to 148° F., showed a greater cream volume after 1 or 2 hours than did the raw milk, and also greater than the same samples showed after 20 hours.

In other words, the tests indicate that pasteurized milk, especially when it is heated to not over 143° F. for 30 minutes, may have an inflated cream volume after about 2 to 5 hours, but that this gradually contracts as the storage period is prolonged.

The fresh raw milk showed a greater cream volume after 2 or 3 hours than it did after 20 hours, but in the old raw milk the maximum cream volume appeared after storage for 20 hours. These tests have an important bearing on experimental work to determine the effect of pasteurization on the creaming ability of market milk. In case the samples are examined after 4 or 5 hours the pasteurized milk will in nearly all cases show a greater cream volume than the raw milk. In the case of tests Nos. 2 and 3 the old raw milk showed an abnormally small cream volume for the butterfat contained, and for that reason the pasteurized samples had greater cream volumes than the raw. excepting those pasteurized at 147° to 148° F.

TABLE 12.—*Rapidity of creaming of raw and pasteurized milk—Laboratory experiment*

[All samples cooled to 42° F. and stored at 48° F.]

| Test No. | Character of milk | Cream volume after number of hours indicated | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ½ | 1 | 1½ | 2 | 2½ | 3 | 3½ | 4 | 5 | 7 | 20 |
| 1 | Fresh raw | 1 | 5 | 9 | 9.5 | 10 | 10.5 | 10.5 | 11 | 11 | 11 | 10 |
| 1 | Pasteurized at 143° to 142° F | 0 | 12 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13.5 | 13 | 11.5 |
| 1 | Pasteurized at 145.75° to 145° F | 0 | 7 | 10.5 | 11.5 | 11.5 | 12 | 12 | 12 | 12 | 12 | 10.5 |
| 1 | Pasteurized at 148° to 147° F | 0 | 1.5 | 5 | 7 | 8.5 | 9 | 9 | 9 | 9 | 9 | 8.5 |
| 2 | Old raw | 0 | 0 | 0 | 3 | 5.5 | 6.5 | 7 | 8 | 8 | 8 | 8.5 |
| 2 | Pasteurized at 143° to 142° F | 0 | 11 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12 | 12 | 11 |
| 2 | Pasteurized at 145.5° to 145° F | 0 | 6 | 10 | 10.5 | 11 | 11 | 11 | 11 | 11 | 11 | 10.5 |
| 2 | Pasteurized at 148° to 147° F | 0 | 0 | 0 | 3 | 4.5 | 5.5 | 5.5 | 6 | 6.5 | 6.5 | 7.5 |
| 3 | Old raw | 0 | 0 | 0 | 4.5 | 6 | 7 | 7.5 | 7.5 | 7.5 | 8 | 8.5 |
| 3 | Pasteurized at 143° to 142° F | 0 | 11 | 13 | 13 | 13 | 13 | 13 | 13 | 12.5 | 12.5 | 11.5 |
| 3 | Pasteurized at 145.5° to 145° F | 0 | 6 | 7 | 8.5 | 8.5 | 8.5 | 8.5 | 9 | 9 | 10 | 9.5 |
| 3 | Pasteurized at 148° to 147° F | 0 | 0 | 0 | 3 | 4.5 | 5.5 | 5.5 | 5.5 | 5.5 | 6.5 | 7.5 |
| 4 | Fresh raw | 0 | 0 | 18 | 18.5 | 19 | 19 | 19 | 18.5 | 18 | 18 | 16.5 |
| 4 | Pasteurized at 143° to 142° F | 0 | 17.5 | 17.5 | 18.5 | 18.5 | 18.5 | 18 | 17.5 | 17.5 | 17.5 | 15.5 |
| 4 | Pasteurized at 145.5° to 145° F | 0 | 15 | 15.5 | 16 | 16 | 16 | 15.5 | 15.5 | 15.5 | 15.5 | 14.5 |
| 4 | Pasteurized at 148° to 147° F | 0 | 3 | 6 | 8 | 9 | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 | 11 |

## EFFECT OF AGE AND RECREAMING OF RAW MILK

Tests were made in the laboratory to determine what effect, if any, the age and the recreaming of raw milk have on its creaming ability.

In Table 13 are shown the results of these tests. The same milk was used in all cases, the only difference being in its age and the number of times it had been recreamed. Sample No. 1 was fresh milk three hours old and showed a cream volume of 13. Sample No. 2 was recreamed when six hours old and showed a cream volume of 12. Samples 3 and 4 also showed a cream layer of 12, though recreamed twice and three times, respectively. It appears from these results that recreaming once has as much effect as recreaming two or three times. Sample No. 5 was recreamed four times, while Nos. 6 and 7 were recreamed only once and twice, respectively. All three samples were of the same age when set and when read, and each showed a cream layer of 10.5, indicating that the age of the milk has as much effect as the recreaming after one creaming. Practically the same results were obtained with the experiment shown in Table 14. Here again the oldest milk that had been recreamed only once showed a poorer cream layer than the fresher milk that had been recreamed two or three times.

TABLE 13.—*Effect of age and recreaming on raw milk—Experiment No. 1*

[All samples cooled to 45° F. and stored at 43° F. Butterfat tests of all samples were 3.75 per cent]

| Sample No. | Age | Age when cream volume read | Times recreamed | Butterfat in under layer | Cream volume after 24 hours | |
|---|---|---|---|---|---|---|
| | | | | | In 100 c. c. of milk | Compared with original milk |
| | *Hours* | *Hours* | | *Per cent* | | *Per cent* |
| 1 | 3 | 27 | 0 | ---------- | 13.0 | 100.0 |
| 2 | 6 | 30 | 1 | ---------- | 12.0 | 92.3 |
| 3 | 9 | 33 | 2 | 1.1 | 12.0 | 92.3 |
| 4 | 11 | 35 | 3 | 1.4 | 12.0 | 92.3 |
| 5 | 27 | 51 | 4 | 1.5 | 10.5 | 80.8 |
| 6 | 27 | 51 | 1 | 1.4 | 10.5 | 80.8 |
| 7 | 27 | 51 | 2 | 1.4 | 10.5 | 80.8 |

TABLE 14.—*Effect of age and recreaming on raw milk—Experiment No. 2*

[All samples recreamed at 45° F. All samples cooled to 45° F. and stored at 43° F.]

| Sample No. | Age | Age when cream volume read | Times recreamed | Butterfat in whole milk | Butterfat in under layer | Cream volume after 20 hours | |
|---|---|---|---|---|---|---|---|
| | | | | | | In 100 c. c. of milk | Compared with original milk |
| | *Hours* | *Hours* | | *Per cent* | *Per cent* | | *Per cent* |
| 1 | 7 | 27 | 0 | 4.05 | 1.1 | 13.0 | 100.0 |
| 2 | 10 | 30 | 1 | ---------- | ---------- | 11.5 | 88.5 |
| 3 | 13 | 33 | 2 | ---------- | 2.0 | 10.5 | 80.8 |
| 4 | 16 | 36 | 3 | ---------- | 2.0 | 10.5 | 80.8 |
| 5 | 31 | 51 | 4 | 4.1 | 1.4 | 10.0 | 76.9 |
| 6 | 31 | 51 | 1 | 4.1 | 1.5 | 10.0 | 76.9 |

## EFFECT OF RECREAMING PASTEURIZED MILK

In some localities milk is pasteurized at a central plant and sent in bulk to branch plants where it is bottled. In other cases the milk may be pasteurized in the country and then shipped to the city where it is to be bottled.

In order to determine what effect the recreaming of milk after pasteurization has on the cream volume, several tests were made at commercial milk plants. A sample from a bottle of freshly pasteurized milk used as a control was placed in storage for 20 hours in the graduated cylinder. The original bottle of pasteurized milk after standing for 24 hours in the milk-storage room was thoroughly shaken, and a sample from it was placed in the graduated cylinder and set in storage for 20 hours. The samples were all cooled to 45° F. and held in storage at approximately 40° F. The results of the tests are shown in Table 15. It will be noted that the cream volume on the recreamed pasteurized milk was considerably less than on the control samples, the percentage of decrease varying from 9.1 to 36.4. The butterfat tests checked in all cases.

These tests illustrate clearly the detrimental results as to cream volume of recreaming pasteurized milk after it has stood for 24 hours. Although the practice of bottling milk that has been pasteurized the previous day is not common, the objection to this practice from the standpoint of cream-volume results is clearly shown.

TABLE 15.—*Effect of recreaming pasteurized milk*

| Test No. | Control | | | | Recreamed after 24 hours | | | | Decrease in cream volume | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Temperature | Age when read | Butterfat | Cream volume | Temperature | Age when read | Butterfat | Cream volume | Amount | Per cent |
| | *° F.* | *Hours* | *Per cent* | | *° F.* | *Hours* | *Per cent* | | | |
| 1 | 45 | 28 | 3.95 | 13.5 | 45 | 52 | 3.75 | 11.0 | 2.5 | 18.5 |
| 2 | 45 | 36 | 3.6 | 9.5 | 45 | 60 | 3.6 | 6.5 | 3.0 | 31.6 |
| 3 | 45 | 36 | 3.5 | 11.5 | 45 | 60 | 3.6 | 9.5 | 2.0 | 17.4 |
| 4 | 45 | 36 | 3.6 | 11.0 | 45 | 60 | 3.8 | 8.5 | 2.5 | 22.7 |
| 5 | 45 | 36 | 3.7 | 11.0 | 45 | 60 | 3.7 | 7.0 | 4.0 | 36.4 |
| 6 | 45 | 36 | 3.6 | 9.0 | 45 | 60 | 3.6 | 7.0 | 2.0 | 22.2 |
| 7 | 45 | 60 | 3.7 | 11.0 | 45 | 84 | 3.7 | 10.0 | 1.0 | 9.1 |

## EFFECT OF PUMPING MILK

### LABORATORY TESTS

Experiments were conducted to determine the effect of pumping, if any, on the creaming ability of raw and pasteurized milk. Four types of pumps were installed and milk was pumped through each at various temperatures. The following types of pumps were used: (1) Rotary pump (about 800 r. p. m.); (2) centrifugal pump (about 1,800 r. p. m.); (3) piston pump; and (4) piston pump (valveless). The results of these tests are shown in Table 16.

TABLE 16.—*Effect of pumping milk at various temperatures*

| Sample No. | Description | Temperature at which sample was pumped | Temperature to which cooled before storage | Cream volume | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Control sample (before pumping) | Pumped through— | | | |
| | | | | | Centrifugal pump | Piston pump | Rotary pump | Valveless piston pump |
| | | *° F.* | *° F.* | | | | | |
| 1 | Old raw | 36 | 38 | 14. 0 | 12. 0 | 13. 0 | 14. 0 | 13. 0 |
| 2 | do | 38 | 38 | 14. 0 | 12. 5 | 12. 5 | ---------- | 11. 0 |
| 3 | Old raw, heated | 84 | 46 | 5. 0 | 6. 0 | 6. 0 | 5. 0 | 10. 0 |
| 4 | do | 70 | 46 | 10. 0 | 12. 5 | 11. 0 | 10. 0 | ---------- |
| 5 | Fresh raw | 60 | 60 | 15. 0 | 14. 0 | 15. 0 | 15. 0 | ---------- |
| 6 | do | 60 | 46 | 14. 0 | 13. 5 | 14. 0 | 14. 0 | ---------- |
| 7 | do | 80 | 80 | 15. 0 | 14. 0 | 14. 5 | 14. 0 | ---------- |
| 8 | do | 80 | 46 | 13. 0 | 14. 0 | 14. 0 | 13. 5 | ---------- |
| 9 | Fresh pasteurized | 145 | 46 | 10. 0 | ---------- | 9. 0 | 10. 0 | ---------- |
| 10 | Old pasteurized | 145 | 46 | 12. 0 | 10. 0 | 11. 0 | 11. 5 | ---------- |
| 11 | do | 110 | 46 | 11. 0 | 10. 0 | 10. 0 | 11. 0 | 11. 0 |
| 12 | do | 108 | 46 | 12. 0 | 10. 0 | 11. 0 | 11. 0 | 12. 0 |
| 13 | do | 54 | 46 | 12. 0 | 11. 0 | 10. 0 | 12. 0 | 10. 5 |
| 14 | do | 48 | 48 | 9. 0 | 7. 0 | 8. 5 | 7. 5 | 8. 0 |
| 15 | do | 45 | 45 | 12. 0 | ---------- | ---------- | ---------- | 12. 0 |
| 16 | Old pasteurized, cooled in vat to 108° F | 45 | 45 | 8. 0 | 8. 0 | 8. 0 | 8. 0 | ---------- |

Sample No. 1 was old raw milk, and pumping it at 36° F. affected the cream volume only slightly. Sample No. 4 was the same as No. 1, except that the milk was heated to 70°. The control as well as the pumped samples had less cream volume than sample No. 1, as did also sample No. 3, heated to 84°.

Sample No. 2 was old raw milk taken from the storage room at 38°. It will be noted that pumping seemed to have a detrimental effect on this milk. The control sample was immediately placed in storage and showed a better cream volume than any of the pumped samples.

Sample No. 3 was old raw milk heated to 84° F. The cream layer was considerably injured on the control as well as on the pumped samples. The cream volume on a sample of this milk before it was heated was 14. This corroborates the results in other tests, which indicate that agitation of milk at certain temperatures has a detrimental effect on its creaming ability.

Sample No. 5 was cooled immediately from 80° to 60° F. The milk was pumped through the various pumps at 60°, and the samples were placed in storage without further cooling. It will be noted that a better cream volume was obtained on the No. 5 samples when they were not cooled than on the No. 6 samples which were cooled to 46°. Agitation at that temperature (60° F.) apparently injured the cream volume.

Sample No. 6 was cooled from 80° to 60° F., and after pumping the pumped samples were all cooled to 46° and placed in storage.

The No. 7 samples were pumped at 80° F. through the various pumps, and the samples with the control were placed in storage without cooling. Pumping affected this milk only slightly.

The control on sample No. 8 was cooled from 80° to 46° F. before placing in storage. The milk was pumped at 80°, and all samples were cooled to 46°. The cream volume on the control sample in this case was apparently injured by the agitation in handling and in cooling. It will be noted that the No. 8 sample, after being pumped, had practically the same cream volume as samples 5, 6, and 7 after being pumped.

Pumping pasteurized milk at 145° F. (samples 9 and 10) had little effect on the cream volume with any of the pumps used.

Sample No. 11 was milk cooled in the vat after pasteurization to 110° F. Two of the pumped samples were only slightly lower in cream volume than the control, although all samples, including the control, had a greatly decreased cream volume compared with the original milk.

Sample No. 12 was old milk pasteurized and immediately cooled to 108° F. before pumping. Pumping at this temperature had a slight effect on the cream volume.

Sample No. 13 was the same as No. 12, except that it was cooled to 54° F. The samples after being pumped at 54° were cooled to 46° before placing in storage. Pumping the milk at this temperature also had only a slight effect on the cream volume.

Sample No. 14 after pasteurization was cooled slowly. The pumped samples showed a cream volume slightly less than the control samples, although the cream volume of all these samples was decreased considerably as a result of the slow cooling.

The results of the tests on pumping milk with the four pumps indicate the following:

1. Pumping raw milk at temperatures between 36° and 50° F. and pasteurized milk at 145° had practically no effect on the cream volume. These are the temperatures at which milk is most commonly pumped at commercial plants.
2. Pumping and agitation at certain temperatures, especially between 110° and 60° F., caused a reduction in the cream volume.

### EFFECT OF PUMPING RAW MILK AT COMMERCIAL PLANTS

Further tests were conducted at milk plants to determine the effect of pumping raw milk under commercial conditions. The results at plants where the raw milk was pumped are shown in Table 17. The control samples upon which the differences in cream volume are computed were raw milk collected from the receiving vat immediately after being emptied from the producers' cans and just prior to pumping. A summary of the results obtained in the investigations shows that in seven instances there was no change in the cream volume, while in most of the other cases the percentage of decrease was small. The average loss in cream volume on the 13 tests included in these tables was 2.3 per cent. At the plants investigated pumping raw milk from the weigh can to the receiving vat caused only a slight reduction in the cream volume.

TABLE 17.—*Effect of pumping raw milk at commercial plants*

| Test number | Temperature | Cream volume [1] | | Decrease in cream volume | | Type of pump |
|---|---|---|---|---|---|---|
| | | Control | Pumped | Amount | Per cent | |
| | °F. | | | | | |
| 1 | 70 | 14.75 | 14.50 | 0.25 | 1.7 | Rotary, 180 r. p. m. |
| 2 | 67 | 17.0 | 17.0 | 0 | 0 | Centrifugal, 1,500 r. p. m. |
| 3 | 66 | 16.0 | 16.0 | 0 | 0 | Do. |
| 4 | 44 | 14.0 | 14.0 | 0 | 0 | Do. |
| 5 | 61 | 13.5 | 13.5 | 0 | 0 | Piston, 25 s. p. m. |
| 6 | 47 | 14.75 | 14.0 | .75 | 5.1 | Centrifugal, 1,500 r. p. m. |
| 7 | 32–46 | 13.5 | 13.5 | 0 | 0 | Do. |
| 8 | 70 | 16.0 | 15.0 | 1.0 | 6.3 | Rotary, 180 r. p. m. |
| 9 | 33 | 13.5 | 13.5 | 0 | 0 | Centrifugal, 1,500 r. p. m. |
| 10 | 43 | 12.0 | 11.5 | .5 | 4.2 | Do. |
| 11 | 64 | 14.0 | 14.0 | 0 | 0 | Piston, 24 s. p. m. |
| 12 | 60 | 13.0 | 12.5 | .5 | 3.8 | Do. |
| 13 | 63 | 16.0 | 14.5 | 1.5 | 9.4 | Do. |

[1] In all cases the butterfat of the control and pumped samples was the same.

### EFFECT OF PUMPING PASTEURIZED MILK AT COMMERCIAL PLANTS

Seven tests were conducted at commercial plants where the milk was pumped after pasteurization. The results are shown in Table 18. It will be noted that there was no reduction in any instance as a result of pumping the milk. Sample No. 5 showed a slightly greater cream volume after pumping, which was undoubtedly due to experimental error. In all cases the butterfat tests of the control and pumped samples were the same. Although the number of tests made is comparatively small, they plainly indicate that pumping pasteurized milk at temperatures between 145° and 115° F. has no harmful effect on the creaming ability of the milk. The results corroborate the laboratory tests shown in Table 16, where it was found that the cream volume was only slightly affected by pumping the hot pasteurized milk.

TABLE 18.—*Effect of pumping pasteurized milk at commercial plants*

| Test No. | Temperature | Cream volume | | Increase or decrease in cream volume | | Type of pump |
|---|---|---|---|---|---|---|
| | | Control | Pumped | Amount | Per cent | |
| | °F. | | | | | |
| 1 | 149 | 11.5 | 11.5 | 0 | 0 | Centrifugal, 1,500 r. p. m. |
| 2 | 129 | 11.5 | 11.5 | 0 | 0 | Do. |
| 3 | 120 | 13.5 | [1] 13.5 | 0 | 0 | Rotary, 180 r. p. m. |
| 4 | 120 | 13.0 | [1] 13.0 | 0 | 0 | Do. |
| 5 | 115 | 10.5 | 11.0 | +0.5 | +4.7 | Piston, 80 s. p. m. |
| 6 | 115 | 12.0 | 12.0 | 0 | 0 | Do. |
| 7 | 115 | 15.0 | 15.0 | 0 | 0 | Centrifugal, 1,800 r. p. m. |

[1] Also filtered.

## EFFECT OF HOLDING MILK AND OF AGITATING IT AT VARIOUS TEMPERATURES BEFORE AND AFTER PASTEURIZATION

The tests on the effect of pumping milk indicated that the temperature at which the milk was pumped was of much more importance than the pumping itself. Tests were therefore undertaken to determine if possible the critical temperatures at which it is detrimental to the cream volume to handle or agitate milk.

Milk was heated in a can which was placed in hot water at a temperature of not over 155° F. Three samples were taken at various temperatures while the milk was being pasteurized and while it was being subsequently cooled. The first sample in each group was cooled at once to 46°, the second was allowed to stand without agitation for 30 minutes and then cooled to 46°, and the third sample was agitated for 30 minutes and then cooled to 46°. The results of the first two tests are shown in Tables 19 and 20.

The data in the tables seem to indicate that holding milk or agitating it for any length of time at temperatures between 60° and 120° F. has generally a detrimental effect on the cream volume. The most marked effect at these temperatures occurred in the milk after pasteurization. Samples 5 and 6 in Table 20 were set at 130° and 120°, respectively, but before the expiration of the 30-minute holding period the temperature had dropped to 110°; this may account for the decrease in the cream volume in these samples.

Table 19.—*Effect of holding milk and of agitating it for 30 minutes at various temperatures before and after pasteurization—First experiment*

[All samples cooled to 46° F. before being placed in storage]

| Sample No. | Description | Temperature at which held and agitated | Cream volume after 20 hours | | |
|---|---|---|---|---|---|
| | | | Control (cooled at once) | Allowed to stand one-half hour before cooling | Held and agitated for one-half hour before cooling |
| | | *° F.* | | | |
| 1 | Fresh raw milk, butterfat 4.95 per cent | 60 | 17.5 | 10.0 | 14.5 |
| 2 | Heated to 70° | 70 | 17.0 | 18.0 | 16.0 |
| 3 | Heated to 80° | 80 | 17.0 | 17.5 | 16.0 |
| 4 | Heated to 90° | 90 | 16.5 | 15.0 | 15.5 |
| 5 | Heated and held 30 minutes | 145 | 16.0 | 16.0 | 15.0 |
| 6 | Pasteurized milk cooled in tank to 90° | 90 | 16.0 | 13.0 | 13.0 |
| 7 | Pasteurized milk cooled in tank to 80° | 80 | 16.0 | 13.5 | 13.0 |
| 8 | Pasteurized milk cooled in tank to 70° | 70 | 15.0 | 13.0 | 12.5 |
| 9 | Pasteurized milk cooled in tank to 60° | 60 | 13.5 | 14.0 | 12.5 |

Table 20.—*Effect of holding milk and of agitating it for 30 minutes at various temperatures before and after pasteurization—Second experiment*

[All samples cooled to 46° F. before being placed in storage]

| Sample No. | Description | Temperature at which held and agitated | Cream volume after 20 hours | | |
|---|---|---|---|---|---|
| | | | Control (cooled at once) | Allowed to stand one-half hour before cooling | Held and agitated one-half hour before cooling |
| | | *° F.* | | | |
| 1 | Raw milk, butterfat 3.60 per cent | 45 | 14.0 | ---------- | ---------- |
| 2 | Heated to 60° | 60 | 14.0 | 12.5 | 13.0 |
| 3 | Heated to 70° | 70 | 13.5 | 12.5 | 11.0 |
| 4 | Heated to 145° for 30 minutes | 145 | 11.0 | ---------- | 11.0 |
| 5 | Cooled to 130° (110° at end of holding) | 130–110 | 11.0 | 10.0 | 9.0 |
| 6 | Cooled in can to 120° (110° at end of holding) | 120–110 | 11.0 | 9.5 | 9.5 |
| 7 | Cooled in can to 110° | 110 | 11.0 | 9.0 | 8.5 |
| 8 | Cooled in can to 100° | 100 | 11.0 | 9.0 | 8.5 |
| 9 | Cooled in can to 90° | 90 | 11.0 | 8.5 | 8.5 |
| 10 | Cooled in can to 80° | 80 | 10.5 | 8.0 | 6.5 |
| 11 | Cooled in can to 70° | 70 | 9.0 | 8.5 | 7.5 |
| 12 | Cooled in can to 60° | 60 | 9.0 | 8.0 | 8.0 |

In Table 21 are shown the results of a similar test where the samples were held and agitated for 15 minutes. The results are similar to those in the previous tables, except that during the heating period the holding and agitating had very little effect. Samples that were held and agitated for 15 minutes at various temperatures between 90° and 60° F. after pasteurization showed a decrease in cream volume, as was also shown in Tables 19 and 20.

TABLE 21.—*Effect of allowing milk to stand, and also of agitation for 15 minutes at various temperatures before and after pasteurization*

[All samples cooled to 45° F. before being placed in storage]

| Sample No. | Description | Temperature at which held and agitated | Cream volume after 20 hours | | |
|---|---|---|---|---|---|
| | | | Control (cooled at once) | Allowed to stand 15 minutes | Held and agitated for 15 minutes before cooling |
| | | °F. | | | |
| 1 | Fresh milk, butterfat 4.95 per cent | 48 | 17.5 | | |
| 2 | Heated to 70° | 70 | 18.0 | 17.5 | 17.5 |
| 3 | Heated to 85° | 85 | 17.0 | 16.5 | 15.5 |
| 4 | Heated to 92° | 92 | 17.0 | 17.0 | 16.5 |
| 5 | Heated to 100° | 100 | 17.0 | 16.5 | 16.5 |
| 6 | Heated to 110° | 110 | 17.0 | 16.5 | 16.5 |
| 7 | Heated to 120° | 120 | 17.0 | 17.0 | 17.0 |
| 8 | Heated to 130° | 130 | 17.0 | 17.0 | 17.0 |
| 9 | Heated to 145° | 145 | 17.0 | | |
| 10 | Heated to 145° for 30 minutes | 145 | 16.0 | | |
| 11 | Cooled in can to 90° | 90 | 14.0 | 12.0 | 12.0 |
| 12 | Cooled in can to 70° | 70 | 13.5 | 12.5 | 12.0 |
| 13 | Cooled in can to 60° | 60 | 13.0 | 12.5 | 12.5 |

The data in Tables 19, 20, and 21 indicate clearly that holding or agitating milk for any length of time at temperatures between 120° and 60° after pasteurization has a detrimental effect on the cream volume. The effect of such holding and agitating on samples taken at different temperatures while the milk was being raised to the pasteurization temperature was much less marked. The data plainly indicate that it is not advisable to cool milk in the vat below 120° to 110° F; it should be cooled from that temperature to below 50° over a separate cooler. The data also indicate, though less emphatically, that the milk should be heated during pasteurization from 60° to 110° F. as quickly as possible and with a minimum of agitation. Agitation of the milk at 145° had very little effect on the cream volume. It will be noted that at temperatures between 110° and 60° F. the milk that was agitated had a poorer cream volume than that which was not agitated; also that in all cases the milk that was held without agitation at temperatures below 120° showed a poorer cream volume than that which was immediately cooled.

The results of these tests have a practical bearing on the commercial handling of market milk. They show clearly the advantages of cooling milk quickly after pasteurization, with as little agitation as possible between the temperatures of 120° and 60° F. They indicate that it is detrimental to pump the milk at these temperatures and also to cool in the vat below about 120° F. after pasteurization. Best results are obtained by cooling from 120° to below 50° over a separate cooler.

## EFFECT OF CLARIFYING RAW MILK

In Table 22 are shown the results of clarifying milk at commercial plants. The control samples from which the differences in cream volume are computed in this table were from the raw milk just prior to entering the clarifier. In some instances it had been pumped, depending upon the routine practice at the particular plant. The results indicate that clarification of raw milk at a temperature of approximately 60° F. does not materially affect the cream volume. Of nine samples clarified at 60° F. to 64° F., four showed no change in cream volume, while the other five showed decreases ranging from 3.6 to 7.7 per cent, the average decrease for the nine tests being 3.6 per cent. This slight decrease in itself would be of practically no commercial importance, but it is a contributing factor; and, if added to other steps in the processing which also decrease the cream volume, it must be recognized as important.

TABLE 22.—*Effect of clarifying raw milk at commercial plants*

| Test No. | Temperature | Control milk | | Clarified milk | | Increase or decrease in cream volume | | Increase or decrease in butterfat of under layer |
|---|---|---|---|---|---|---|---|---|
| | | Cream volume | Butterfat | Cream volume | Butterfat | Amount | Per cent | |
| | *° F.* | | *Per cent* | | *Per cent* | | | *Per cent* |
| 1 | 62 | 14.0 | 3.6 | 14.0 | 3.6 | 0 | 0 | Not tested. |
| 2 | 62 | 13.5 | 3.7 | 13.5 | 3.7 | 0 | 0 | Not tested. |
| 3 | 64 | 14.0 | 3.7 | 13.0 | 3.7 | −1.0 | −7.1 | Not tested. |
| 4 | 60 | 13.0 | 3.8 | 12.0 | 3.8 | −1.0 | −7.7 | Not tested. |
| 5 | 62 | 14.5 | ---------- | 14.5 | ---------- | 0 | 0 | Not tested. |
| 6 | 46 | 14.0 | 3.9 | 13.0 | 3.85 | −1.0 | −7.1 | +14.3 |
| 7 | 64 | 14.0 | 3.8 | 13.5 | 3.7 | − .5 | −3.6 | Not tested. |
| 8 | 64 | 16.0 | 3.5 | 15.0 | 3.6 | −1.0 | −6.2 | +33 |
| 9 | 88 | 12.5 | 3.5 | 11.5 | 3.5 | −1.0 | −8.0 | +33 |
| 10 | 88 | 13.5 | 3.5 | 11.0 | 3.5 | −2.5 | −18.5 | Not tested. |
| 11 | 47 | 14.0 | 3.95 | 13.5 | 3.9 | − .5 | −3.6 | +10 |
| 12 | 46 | 13.5 | 4.0 | 12.5 | 4.0 | −1.0 | −7.4 | +18.1 |
| 13 | 70 | 15.0 | 3.65 | 14.0 | 3.65 | −1.0 | −6.6 | +22.2 |
| 14 | 60 | 13.5 | 3.7 | 13.5 | 3.7 | 0 | 0 | 0 |
| 15 | 64 | 13.0 | 3.7 | 12.0 | 3.7 | −1.0 | −7.7 | +6.6 |

Only two tests were made at plants where the milk was clarified at 88° F. At these two plants the cream volume was decreased by 8.0 and 18.5 per cent, respectively.

It is impossible to draw definite conclusions from so small a number of tests, but the results of those that were made indicate that there is only a slight decrease in cream volume when milk is clarified at approximately 60° F. or below, whereas at the higher temperatures there is more danger of injuring the cream volume.

## EFFECT OF FILTERING MILK

Mechanical filters to remove the insoluble dirt from milk have been developed to a considerable degree in the past few years. At some plants the milk is filtered before pasteurization, although the more common practice is to filter it after it has been heated to 145° F. or after it has been heated and held.

Only one test was made at a plant where the raw milk was filtered. At this plant the milk was preheated to 70° F. before being pumped through the filter. A sample taken between the pump and filter showed a cream volume of 14.5, whereas a sample taken at the outlet of the filter showed 14, or a reduction of only 3.4 per cent.

Five tests were made at plants where the pasteurized milk was filtered. The results are shown in Table 23.

The control sample was taken just before the milk entered the filter, and with the exception of test No. 1 the filtered sample was taken at the outlet of the filter.

It will be noted that there was a reduction in cream volume in only one instance, test No. 1. In this instance the sample was taken after it went over the cooler, which may have been the cause of the decrease in cream volume. In all cases the milk was filtered before it had been cooled below 115° F. These investigations would indicate that filtering hot pasteurized milk has little, if any, effect on the cream volume.

TABLE 23.—*Effect of filtering pasteurized milk*

| Test No. | Temperature | Cream volume | | | Increase or decrease after filtering | |
|---|---|---|---|---|---|---|
| | | Control milk | Pumped milk | Pumped and filtered milk | Amount | Per cent |
| | ° F. | | | | | |
| 1 | 149 | 11.5 | 11.5 | [1] 10.0 | −1.5 | −13.0 |
| 2 | 120 | 13.5 | ---------- | 13.5 | 0 | 0 |
| 3 | 120 | 13.5 | 13.0 | 13.0 | 0 | 0 |
| 4 | 115 | 10.5 | 11.0 | 11.0 | 0 | 0 |
| 5 | 115 | 12.0 | 12.0 | 12.0 | 0 | 0 |

[1] Sample taken after milk went over the cooler.

## INFLUENCE OF VARIOUS SHAPES OF MILK BOTTLES ON DEPTH OF CREAM LAYER

It has been noted that there may be considerable variation in the depth of the cream volume in the same milk, if placed in bottles of different heights and shapes. In many cities there are no bottle exchanges and the dealers do not have a uniform stock of bottles. Some plant owners purposely purchase bottles designed to extend the depth of the cream layer, and others apparently do not consider this feature. The bottles rapidly become interchanged between dealers, and as a result each pasteurization plant uses bottles that vary considerably in shape and height.

Figure 1 shows various-shaped milk bottles and the variation in the depth of the cream layer which results. Equal quantities of the same milk were placed in these bottles and they were allowed to stand at a uniform temperature for 20 hours. A measurement of the depth of the cream layer is as follows:

| | |
|---|---|
| Bottle 1 | $2\frac{13}{16}$ inches. |
| Bottle 2 | 3⅜ inches. |
| Bottle 3 | 3¼ inches. |
| Bottle 4 | $2\frac{13}{16}$ inches. |
| Bottle 5 | $3\frac{7}{16}$ inches. |
| Bottle 6 | $3\frac{5}{16}$ inches. |

Bottle 5 shows an increase in the cream depth of approximately 22 per cent as compared with bottles Nos. 1 and 4. This is an apparent variation in cream volume of more than the actual variations obtained in many of the steps of processing discussed in this bulletin. A consumer receiving two quarts of milk, one in a bottle with a wide neck and the other in a bottle with a narrow neck designed to extend the cream layer, would undoubtedly note the lack of uniformity in the apparent richness of the milk. Such variations may give rise to more complaints on the part of the consumer than a slight reduction in the cream depth as a result of the various processes in the plant.

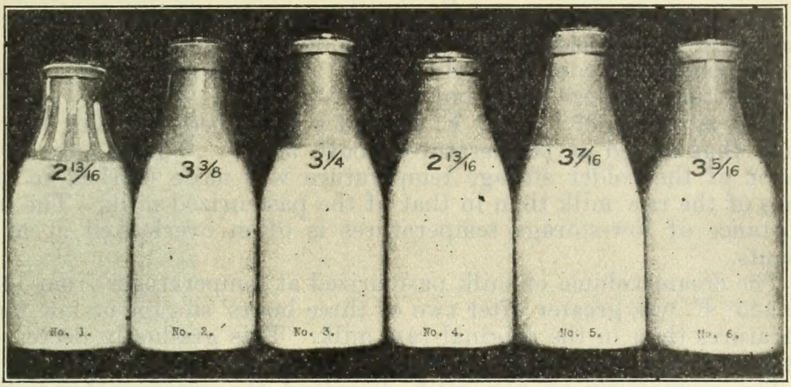

FIG. 1.—Effect of various shapes of milk bottle on the apparent cream volume

## SUMMARY AND CONCLUSIONS

Milk heated to 143° F for 30 minutes showed practically no decrease in the cream volume, and in some cases an increase resulted.

Pasteurization at 145° to 146° F. for 30 minutes reduced the cream volume an average of approximately 8 per cent, with considerable variations above and below.

Pasteurization at approximately 148° F. for 30 minutes caused a decrease in cream volume of from 18.5 to 41.7 per cent, with an average decrease of approximately 31 per cent.

The reduction in cream volume due to pasteurization at 145° to 146° F. was not so marked in the case of 24 to 36 hours old milk as in fresh milk, owing to the fact that old milk does not show so deep a cream volume before pasteurization as does fresh milk. Pasteurization of old market milk had a tendency to restore its creaming ability.

The cream volume results showed only slight variations due to the different types of pasteurizing apparatus which were in use at the plants investigated, when factors in the processing other than heating and holding were not involved.

At the particular plants investigated there was practically no difference in the cream volume results from apparatus using a low-temperature heating medium as compared with that using a high-temperature medium, provided the time of heating was approximately the same.

Only a slightly better cream volume was obtained in vat pasteurization when a low-temperature heating medium was forced through the coils by a direct-acting pump, as compared with the ordinary circulation of a heating medium of higher temperature.

The tests to show the effect of agitation during the holding period were not uniform, but the tendency appeared to be slightly in favor of holding the milk without agitation during this period. Moderate agitation during the 30-minute holding period apparently has no appreciable effect on the cream volume.

Milk cooled in tank or vat pasteurizers from 145° to 50° F. showed a poor cream volume. Cooling milk in the tank or vat from 145° F. to 110° or 120°, and then cooling quickly to below 50° F. over a separate cooler resulted in a good cream volume.

The tests showed that cooling milk to a low temperature after pasteurization is necessary in order to obtain a good cream volume. Pasteurized milk cooled to below 45° F. showed a much better cream volume than that cooled to only 50° F. or above.

Milk stored at 38° to 48° F. showed a much better cream volume than that stored at temperatures above 50° F. The difference in favor of the colder storage temperature was more marked in the case of the raw milk than in that of the pasteurized milk. The importance of low-storage temperatures is often overlooked at milk plants.

The cream volume of milk pasteurized at temperatures from 143° to 145° F. was greater after two or three hours' storage at low temperatures than in the original raw milk. This gradually decreased as the storage period was prolonged.

The recreaming of raw milk decreased the cream volume, but after one recreaming the age of the milk was of more importance than the number of times it was recreamed.

The recreaming of pasteurized milk had a detrimental effect on the cream volume. This has a practical significance at plants which bottle pasteurized milk after it has been allowed to cream.

Pumping milk at temperatures between 60° and 120° F. reduced the cream volume to a slight extent in some cases. Pumping raw milk below 60° F. and pumping pasteurized milk at temperatures between 120° and 145° F. with the four types of pumps used had practically no effect on the cream volume.

Allowing milk to stand or to be agitated for 15 minutes or more at temperatures between 60° and 110° F. had generally a detrimental effect on the cream volume. This was more pronounced with milk that was being cooled from the pasteurization temperature than with that which was being heated.

Holding or agitating milk at a temperature of 145° F. had considerably less effect on the cream volume than at temperatures between 60° and 110° F.

Clarifying milk at temperatures between 60° and 65° F. had only a slight effect on the cream volume, though there was a considerable decrease when the milk was clarified at temperatures above 80° F.

Filtering hot milk had practically no effect on the cream volume.

It is evident that a material decrease in the cream volume of the finished product may result from the accumulation of slight decreases brought about by various steps in the process; therefore it is important to minimize as much as possible the decrease in each step.

The various shapes of bottles caused a great difference in the apparent cream volume.

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